120.770: TRANSPORTATION OF RADIOACTIVE MATERIAL

120.771: Purpose and Scope

105 CMR 120.770 establishes requirements for packaging, preparation for shipment, and transportation of radioactive material and apply to any person who transports radioactive material or delivers radioactive material to a carrier for transport.

120.772: Definitions

As used in 105 CMR 120.770, the following definitions apply:

Carrier, means a person engaged in the transportation of passengers or property by land or water as a common, contract, or private carrier, or by civil aircraft.

Closed transport vehicle, means a transport vehicle equipped with a securely attached exterior enclosure that during normal transportation restricts the access of unauthorized persons to the cargo space containing the radioactive material. The enclosure may be either temporary or permanent but shall limit access from top, sides, and ends. In the case of packaged materials, it may be of the "see-through" type.

Exclusive use, means the sole use of a conveyance by a single consignor for which all initial, intermediate, and final loading and unloading are carried out in accordance with the direction of the consignor or consignee. The consignor and the carrier must ensure that any loading or unloading is performed by personnel having radiological training and resources appropriate for safe handling of the consignment. The consignor must issue specific instructions, in writing, for maintenance of exclusive use shipment controls, and include them with the shipping paper information provided to the carrier by the consignor.

Fissile material, means plutonium-238, plutonium-239, plutonium-241, uranium-233, or uranium-235, or any combination of these radionuclides. Unirradiated natural uranium and depleted uranium, and natural uranium or depleted uranium that has been irradiated in thermal reactors only are not included in this definition. [1]

Fissile material package means a fissile material packaging together with its fissile material contents.

Low specific activity (LSA) material, means radioactive material with limited specific activity that satisfies the descriptions and limits set forth below. Shielding materials surrounding the LSA material may not be considered in determining the estimated average specific activity of the package contents. LSA material must be in one of three groups:

S))))))))))))))))))))))))))))))))))))Q

[1] Agency jurisdiction extends only to “special nuclear material in quantities not sufficient to form a critical mass” as defined in 105 CMR 120.001.

120.772: continued

120.772: continued

(1) LSA-I.

(a) Ores containing only naturally occurring radionuclides (*e.g.*, uranium, thorium) and uranium or thorium concentrates of such ores; or,

(b) Solid unirradiated natural uranium or depleted uranium or natural thorium or their solid or liquid compounds or mixtures; or,

(c) Radioactive material, other than fissile material, for which the A_2 value is unlimited; or,

(d) Mill tailings, contaminated earth, concrete, rubble, other bulk debris, and activated material in which the radioactive material is essentially uniformly distributed, and the average specific activity does not exceed 10^{-6} A_2/g.

(2) LSA-II.

(a) Water with tritium concentration up to 0.8 TBq/liter (20.0 Ci/liter); or,

(b) Material in which the radioactive material is essentially uniformly distributed, and the average specific activity does not exceed 10^{-4} A_2/g for solids and gases, and 10^{-5} A_2/g for liquids.

(3) LSA-III. Solids (*e.g.*, consolidated wastes, activated materials) in which:

(a) The radioactive material is essentially uniformly distributed throughout a solid or a collection of solid objects, or is essentially uniformly distributed in a solid compact binding agent (such as concrete, bitumen, ceramic, *etc.*);

(b) The radioactive material is relatively insoluble, or it is intrinsically contained in a relatively insoluble material, so that, even under loss of packaging, the loss of radioactive material per package by leaching, when placed in water for seven days, would not exceed 0.1 A_2; and,

(c) The average specific activity of the solid does not exceed 2×10^{-3} A_2/g.

Low toxicity alpha emitters, means natural uranium, depleted uranium, natural thorium; uranium-235, uranium-238, thorium-232, thorium-228 or thorium-230 when contained in ores or physical or chemical concentrates; or alpha emitters with a half-life of less than ten days.

Maximun normal operating pressure, means the maximum gauge pressure that would develop in the containment system in a period of one year under the heat condition specified in 10 CFR 71.71(c)(1), in the absence of venting, external cooling by an ancillary system, or operational controls during transport.

Natural thorium, means thorium with the naturally occurring distribution of thorium isotopes (essentially 100 weight percent thorium-232).

Normal form radioactive material, means radioactive material which has not been demonstrated to qualify as special form radioactive material.

Packaging, means the assembly of components necessary to ensure compliance with the packaging requirements of 49 CFR Part 173, Subpart I. It may consist of one or more receptacles, absorbent materials, spacing structures, thermal insulation, radiation shielding, and devices for cooling or absorbing mechanical shocks. The vehicle, tie-down system, and auxiliary equipment may be designated as part of the packaging.

Regulations of the U.S. Department of Transportation, means the regulations in 49 CFR Parts 100-189 and Parts 390-397.

Regulations of the U.S. Nuclear Regulatory Commission, means the regulations in 10 CFR 71 for purposes of 105 CMR 120.770.

Special form radioactive material, means radioactive material which satisfies the following conditions:

(1) It is either a single solid piece or is contained in a sealed capsule that can be opened only by destroying the capsule;

(2) The piece or capsule has at least one dimension not less than 5 millimeters (0.2 inch); and,

120.772: continued

(3) It satisfies the test requirements specified by the Nuclear Regulatory Commission. A special form encapsulation designed in accordance with the Nuclear Regulatory Commission requirements in effect June 30, 1983, and constructed prior to July 1, 1985, may continue to be used. A special form encapsulation designed in accordance with the Nuclear Regulatory Commission requirements in effect on March 31, 1996, and constructed prior to April 1, 1998, may continue to be used. A special form encapsulation either designed or constructed after April 1, 1998, must meet requirements of this definition applicable at the time of its design or construction.

Specific activity, of a radionuclide means the activity of a radionuclide per unit mass of that nuclide. The specific activity of a material in which the radionuclide is essentially uniformly distributed is the activity per unit mass of the material.

Surface Contaminated Object (SCO), means a solid object that is not itself classed as radioactive material, but which has radioactive material distributed on any of its surfaces. SCO must be in one of two groups with surface activity not exceeding the following limits:

(1) SCO-I: A solid object on which:

(a) The non-fixed contamination on the accessible surface averaged over 300 cm^2 (or the area of the surface if less than 300 cm^2) does not exceed 4 Bq/cm^2 (10^{-4} microcurie/cm^2) for beta and gamma and low toxicity alpha emitters, or 0.4 Bq/cm^2 (10^{-5} microcurie/cm^2) for all other alpha emitters;

(b) The fixed contamination on the accessible surface averaged over 300 cm^2 (or the area of the surface if less than 300 cm^2) does not exceed $4x10^4$ Bq/cm^2 (1.0 microcurie/cm^2) for beta and gamma and low toxicity alpha emitters, or $4x10^3$ Bq/cm^2 (0.1 microcurie/cm^2) for all other alpha emitters; and,

(c) The non-fixed contamination plus the fixed contamination on the inaccessible surface averaged over 300 cm^2 (or the area of the surface if less than 300 cm^2) does not exceed $4x10^4$ Bq/cm^2 (1 microcurie/cm^2) for beta and gamma and low toxicity alpha emitters, or $4x10^3$ Bq/cm^2 (0.1 microcurie/cm^2) for all other alpha emitters.

(2) SCO-II: A solid object on which the limits for SCO-I are exceeded and on which:

(a) The non-fixed contamination on the accessible surface averaged over 300 cm^2 (or the area of the surface if less than 300 cm^2) does not exceed 400 Bq/cm^2 (10^{-2} microcurie/cm^2) for beta and gamma and low toxicity alpha emitters or 40 Bq/cm^2 (10^{-3} microcurie/cm^2) for all other alpha emitters;

(b) The fixed contamination on the accessible surface averaged over 300 cm^2 (or the area of the surface if less than 300 cm^2) does not exceed $8x10^5$ Bq/cm^2 (20 microcuries/cm^2) for beta and gamma and low toxicity alpha emitters, or $8x10^4$ Bq/cm^2 (2 microcuries/cm^2) for all other alpha emitters; and,

(c) The non-fixed contamination plus the fixed contamination on the inaccessible surface averaged over 300 cm^2 (or the area of the surface if less than 300 cm^2) does not exceed $8x10^5$ Bq/cm^2 (20 microcuries/cm^2) for beta and gamma and low toxicity alpha emitters, or $8x10^4$ Bq/cm^2 (2 microcuries/cm^2) for all other alpha emitters.

Transport index, means the dimensionless number, rounded up to the next tenth, placed on the label of a package to designate the degree of control to be exercised by the carrier during transportation. The transport index is the number expressing the maximum radiation level at one meter (3.3 feet) from the external surface of the package in millisievert (mSv) per hour multiplied by 100 (equivalent to the maximum radiation level in millirem per hour at one meter).

Type A quantity, means a quantity of radioactive material, the aggregate radioactivity of which does not exceed A_1 for special form radioactive material or A_2 for normal form radioactive material, where A_1 and A_2 are given in 105 CMR 120.795: *Appendix A* or may be determined by procedures described in 105 CMR 120.795: *Appendix A*.

Type A package, means a packaging that, together with its radioactive contents limited to A_1 or A_2 as appropriate, meets the requirements of 49 CFR 173.410 and 173.412 and is designed to retain the integrity of containment and shielding required by 105 CMR 120.770 under normal conditions of transport as demonstrated by the tests set forth in 49 CFR 173.465 or 173.466, as appropriate.

120.772: continued

Type B package, means a Type B packaging together with its radioactive contents.[2]

Type B packaging, means a packaging designed to retain the integrity of containment and shielding when subjected to the normal conditions of transport and hypothetical accident test conditions set forth in 10 CFR Part 71.

Type B quantity, means a quantity of radioactive material greater than a Type A quantity.

Uranium - natural, depleted, enriched

(1) Natural uranium, means uranium with the naturally occurring distribution of uranium isotopes (approximately 0.711 weight percent uranium-235, and the remainder by weight essentially uranium-238).

(2) Depleted uranium, means uranium containing less uranium-235 than the naturally occurring distribution of uranium isotopes.

(3) Enriched uranium, means uranium containing more uranium-235 than the naturally occurring distribution of uranium isotopes.

GENERAL REGULATORY PROVISIONS

120.773: Requirement for License

No person shall transport radioactive material or deliver radioactive material to a carrier for transport except as authorized in a general or specific license issued by the Agency or as exempted in 105 CMR 120.774.

120.774: Exemptions

(A) Common and contract carriers, freight forwarders, and warehouse workers who are subject to the requirements of the U.S. Department of Transportation in 49 CFR 170 through 189 or the U.S. Postal Service in the Postal Service Manual (Domestic Mail Manual), Section 124.3 incorporated by reference, 39 CFR 111.11 (1974), and the U.S. Postal Service are exempt from the requirements of 105 CMR 120.770 to the extent that they transport or store radioactive material in the regular course of their carriage for others or storage incident thereto. Common and contract carriers who are not subject to the requirements of the U.S. Department of Transportation or U.S. Postal Service are subject to 105 CMR 120.773 and other applicable requirements of 105 CMR 120.000.

(B) Any licensee is exempt from the requirements of 105 CMR 120.770 to the extent that the licensee delivers to a carrier for transport a package containing radioactive material having a specific activity not greater than 70 Bq/gm (0.002 microcurie per gram).

(C) With the exception of 105 CMR 120.775 and 120.786, a licensee is exempt from all requirements of 105 CMR 120.770, with respect to shipment or carriage of the following packages, provided the packages contain no fissile material, or the fissile material exemption standard of 10 CFR 71.53 are satisfied:

(1) A package containing no more than a Type A quantity of radioactive material;

(2) A package in which the only radioactive material is low specific activity (LSA) material or surface contaminated objects (SCO), provided the external radiation level at three meters from the unshielded material or objects does not exceed 10 mSv/h (1rem/h); or,

(3) Packages transported between locations within the United States which contain only americium or plutonium in special form with an aggregate radioactivity not to exceed 740 Gbq (20 curies).

S)))))))))))))))))))))Q

[2] A Type B package design is designated as B(U) or B(M). B(U) refers to the need for unilateral approval of international shipments; B(M) refers to the need for multilateral approval. No distinction is made in how packages with these designations may be used in domestic transportation. To determine their distinction for international transportation, refer to 49 CFR Part 173. A Type B package approved prior to September 6, 1983 was designated only as Type B. Limitations on its use are specified in 105 CMR 120.778.

120.774: continued

(D) A licensee is exempt from all requirements of 105 CMR 120.770, other than 105 CMR 120.775 and 120.786, with respect to shipment or carriage of low specific activity (LSA) material in group LSA-I, or surface contaminated objects (SCOs) in group SCO-I.

120.775: Transportation of Licensed Material

(A) Each licensee who transports licensed material outside the site of usage, as specified in the Agency license, or where transport is on public highways, or who delivers licensed material to a carrier for transport, shall:

(1) Comply with the applicable requirements, appropriate to the mode of transport, of the regulations of the U.S. Department of Transportation; particularly the regulations of the U.S. Department of Transportation in the following areas:

(a) Packaging - 49 CFR Part 173: Subparts A and B and I.

(b) Marking and labeling - 49 CFR Part 172: Subpart D, §§ 172.400 through 172.407, §§ 172.436 through 172.440, and Subpart E.

(c) Placarding - 49 CFR Part 172: Subpart F, especially §§ 172.500 through 172.519, 172.556, and Appendices B and C.

(d) Accident reporting - 49 CFR Part 171: §§ 171.15 and 171.16.

(e) Shipping papers and emergency information - 49 CFR Part 172: Subparts C and G.

(f) Hazardous material employee training - 49 CFR Part 172: Subpart H.

(g) Hazardous material shipper/carrier registration - 49 CFR Part 107: Subpart G.

(2) The licensee shall also comply with the U.S. Department of Transportation regulations pertaining to the following modes of transportation:

(a) Rail - 49 CFR Part 174: Subparts A through D and K.

(b) Air - 49 CFR Part 175

(c) Vessel - 49 CFR Part 176: Subparts A through F and M.

(d) Public Highway - 49 CFR Part 177 and Parts 390 through 397.

(3) Assure that any special instructions needed to safely open the package are sent to or have been made available to the consignee in accordance with 105 CMR 120.246(E).

(B) If, for any reason, the regulations of the U.S. Department of Transportation are not applicable to a shipment of licensed material, the licensee shall conform to the standards and requirements of 49 CFR Parts 170 through 189 appropriate to the mode of transport to the same extent as if the shipment was subject to the regulations.

120.776: General Licenses for Carriers

(A) A general license is hereby issued to any common or contract carrier not exempt under 105 CMR 120.774 to receive, possess, transport, and store radioactive material in the regular course of their carriage for others or storage incident thereto, provided the transportation and storage is in accordance with the applicable requirements, appropriate to the mode of transport, of the U.S. Department of Transportation insofar as such requirements relate to the loading and storage of packages, placarding of the transporting vehicle, and incident reporting.[3]

(B) A general license is hereby issued to any private carrier to transport radioactive material, provided the transportation is in accordance with the applicable requirements, appropriate to the mode of transport, of the U.S. Department of Transportation insofar as such requirements relate to the loading and storage of packages, placarding of the transporting vehicle, and incident reporting.[3]

(C) Persons who transport radioactive material pursuant to the general licenses in 105 CMR 120.776(A) or (B) are exempt from the requirements of 105 CMR 120.200 and 120.750 to the extent that they transport radioactive material.

$)))))))))))))))))))))))))))))))))Q

[3] Notification of an incident shall be filed with, or made to, the Agency as prescribed in 49 CFR, regardless of, and in addition to, notification made to U.S. Department of Transportation or other agencies.

120.777: General License: Nuclear Regulatory Commission - Approved Packages

(A) A general license is hereby issued to any licensee to transport, or to deliver to a carrier for transport, licensed material in a package for which a license, certificate of compliance, or other approval has been issued by the Nuclear Regulatory Commission.

(B) This general license applies only to a licensee who:

(1) Has a copy of the specific license, certificate of compliance, or other approval by the Nuclear Regulatory Commission of the package and has the drawings and other documents referenced in the approval relating to the use and maintenance of the packaging and to the actions to be taken prior to shipment;

(2) Complies with the terms and conditions of the license, certificate, or other approval by the Nuclear Regulatory Commission, as applicable, and the applicable requirements of 105 CMR 120.770;

(3) Prior to the licensee's first use of the package, has registered with the Nuclear Regulatory Commission; and,

(4) Has a quality assurance program required by 105 CMR 120.790.

(C) The general license in 105 CMR 120.777(A) applies only when the package approval authorizes use of the package under this general license.

(D) For a Type B or fissile material package, the design of which was approved by the Nuclear Regulatory Commission before April 1, 1996, the general license is subject to the additional restrictions of 105 CMR 120.778.

120.778: General License - Previously Approved Packages

(A) A Type B package previously approved by the Nuclear Regulatory Commission, but not designated as B(U) or B(M) in the identification number of the Nuclear Regulatory Commission Certificate of Compliance, may be used under the general license of 105 CMR 120.777 with the following additional conditions:

(1) Fabrication of the packaging was satisfactorily completed before August 31, 1986, as demonstrated by application of its model number in accordance with Nuclear Regulatory Commission regulations at 10 CFR 71.85(c);

(2) A package used for a shipment to a location outside the United States is subject to multilateral approval, as defined in U.S. Department of Transportation regulations at 49 CFR 173.403; and,

(3) A serial number that uniquely identifies each packaging which conforms to the approved design is assigned to, and legibly and durably marked on, the outside of each packaging.

(B) A Type B(U) package, a Type B(M) package, a low specific activity (LSA) material package or a fissile material package, previously approved by the Nuclear Regulatory Commission but without the designation "-85" in the identification number of the Nuclear Regulatory Commission Certificate of Compliance, may be used under the general license of 105 CMR 120.777 with the following additional conditions:

(1) Fabrication of the packaging was satisfactorily completed before April 1, 1999, as demonstrated by application of its model number in accordance with Nuclear Regulatory Commission regulations at 10 CFR 71.85(c);

(2) A package used for a shipment to a location outside the United States is subject to multilateral approval as defined in U.S. Department of Transportation regulations at 49 CFR 173.403; and,

(3) A serial number which uniquely identifies each packaging which conforms to the approved design is assigned to and legibly and durably marked on the outside of each packaging.

120.779: General License: U.S. Department of Transportation Specification Container

(A) A general license is issued to any licensee to transport, or to deliver to a carrier for transport, licensed material in a specification container for fissile material or for a Type B quantity of radioactive material as specified in 49 CFR Parts 173 and 178.

120.779: continued

(B) This general license applies only to a licensee who:
(1) Has a copy of the specification;
(2) Complies with the terms and conditions of the specification and the applicable requirements of 105 CMR 120.770; and,
(3) Has a quality assurance program as required by 105 CMR 120.790.

(C) The general license in 105 CMR 120.779(A) is subject to the limitation that the specification container may not be used for a shipment to a location outside the United States except by multilateral approval as defined in 49 CFR 173.403.

120.780: General License - Use of Foreign Approved Package

(A) A general license is issued to any licensee to transport, or to deliver to a carrier for transport, licensed material in a package the design of which has been approved in a foreign national competent authority certificate which has been revalidated by the U.S. Department of Transportation as meeting the applicable requirements of 49 CFR 171.12.

(B) This general license applies only to international shipments.

(C) This general license applies only to a licensee who:
(1) Has a copy of the applicable certificate, the revalidation, and the drawings and other documents referenced in the certificate relating to the use and maintenance of the packaging and to the actions to be taken prior to shipment;
(2) Complies with the terms and conditions of the certificate and revalidation, and with the applicable requirements of 105 CMR 120.770; and,
(3) Has a quality assurance program approved by the Nuclear Regulatory Commission.

120.781: General License: Fissile Material, Limited Quantity Per Package

(A) A general license is hereby issued to any licensee to transport fissile material, or to deliver fissile material to a carrier for transport, if the material is shipped in accordance with 105 CMR 120.781.

(B) This general license applies only to a licensee who has a quality assurance program approved by the Nuclear Regulatory Commission as satisfying the provisions of 10 CFR Part 71 subpart H.

(C) Except as provided in 105 CMR 120.781(D), this general license applies only when a package contains no more than a Type A quantity of radioactive material, including only one of the following:
(1) Up to 40 grams of uranium-235;
(2) Up to 30 grams of uranium-233;
(3) Up to 25 grams of the fissile radionuclides of plutonium, except that for encapsulated plutonium-beryllium neutron sources in special form, an A_1 quantity of plutonium may be present; or,
(4) A combination of fissile radionuclides in which the sum of the ratios of the amount of each radionuclide to the corresponding maximum amounts in 105 CMR 120.781(C)(1), (2), and (3) does not exceed unity.

(D) For packages where fissile material is mixed with substances having an average hydrogen density greater than water, this general license applies only when a package contains no more than a Type A quantity of radioactive material, including only one of the following:
(1) Up to 29g of uranium-235;
(2) Up to 18g of uranium-233;
(3) Up to 18g of fissile radionuclides of plutonium; or,
(4) A combination of fissile radionuclides in which the sum of the ratios of the amount of each radionuclide to the corresponding maximum amounts in 105 CMR 120.781(D) (1), (2), and (3) does not exceed unity.

120.781: continued

(E) Except for the beryllium contained within the special form plutonium-beryllium sources authorized in 105 CMR 120.781(C), this general license applies only when beryllium , graphite, or hydrogenous material enriched in deuterium is not present in quantities exceeding 0.1% of the fissile material mass.

(F)(1) Except as specified in 105 CMR 120.781(F)(2) for encapsulated plutonium-beryllium sources, this general license applies only when, a package is labeled with a transport index not less than the number given by the following equation, where the package contains x grams of uranium-235, y grams of uranium-233, and z grams of the fissile radionuclides of plutonium:

$$\text{Minimum Transport Index} = (0.25x + 0.33y + 0.4z).$$

(2) For a package in which the only fissile material is in the form of encapsulated plutonium-beryllium neutron sources in special form, the transport index based on criticality considerations may be taken as 0.025 times the number of grams of the fissile radionuclides of plutonium.

(3) Packages which have a transport index greater than ten are not authorized under the general license provisions of 105 CMR 120.770.

120.782: General License: Fissile Material, Limited Moderator Per Package

(A) A general license is hereby issued to any licensee to transport fissile material, or to deliver fissile material to a carrier for transport, if the material is shipped in accordance with 105 CMR 120.782.

(B) This general license applies only when all of the following requirements are met:

(1) The package contains no more than a Type A quantity of radioactive material;

(2) Neither beryllium nor hydrogenous material enriched in deuterium is present;

(3) The total mass of graphite present does not exceed 7.7 times the total mass of uranium-235 plus plutonium;

(4) Substances having a higher hydrogen density than water, for example, certain hydrocarbon oils, are not present, except that polyethylene may be used for packing or wrapping;

(5) Uranium-233 is not present, and the amount of plutonium does not exceed 1% of the amount of uranium-235;

(6) The amount of uranium-235 is limited as follows:

(a) If the fissile radionuclides are not uniformly distributed, the maximum amount of uranium-235 per package may not exceed the value given TABLE I of 105 CMR 120.782; or,

(b) If the fissile radionuclides are distributed uniformly, for example, cannot form a lattice arrangement within the packaging, the maximum amount of uranium-235 per package may not exceed the value given in TABLE II of 105 CMR 120.782; and,

(7) The transport index of each package based on criticality considerations is taken as ten times the number of grams of uranium-235 in the package divided by the maximum allowable number of grams per package in accordance with 105 CMR 120.782: TABLE I or TABLE II as applicable.

120.782: continued

TABLE I
PERMISSIBLE MASS OF URANIUM-235 PER FISSILE MATERIAL PACKAGE
[NONUNIFORM DISTRIBUTION]

Uranium enrichment in weight percent of uranium-235 not exceeding	Permissible maximum grams of uranium-235 per package
24	40
20	42
15	45
11	48
10	51
9.5	52
9	54
8.5	55
8	57
7.5	59
7	60
6.5	62
6	65
5.5	68
5	72
4.5	76
4	80
3.5	88
3	100
2.5	120
2	164
1.5	272
1.35	320
1	680*
0.92	1200*

120.782: continued

TABLE II
PERMISSIBLE MASS OF URANIUM-235 PER FISSILE MATERIAL PACKAGE
[UNIFORM DISTRIBUTION]

Uranium enrichment in weight percent of uranium-235 not exceeding	Permissible maximum grams of uranium-235 per package
4	84
3.5	92
3	112
2.5	148
2	240
1.5	560*
1.35	800*

*Pursuant to the Agency's agreement with the Nuclear Regulatory Commission, jurisdiction extends only to 350 grams of uranium-235.

(C) The licensee has a quality assurance program approved by Nuclear Regulatory Commission.

OPERATING CONTROLS AND PROCEDURES

120.783: Assumptions as to Unknown Properties of Fissile Material

(A) Applicability of operating controls and procedures: A licensee subject to 10 CFR 120.770, who, under a general or specific license, transports licensed material or delivers licensed material to a carrier for transport, shall comply with the requirements of 10 CFR 71 subpart G, with the quality assurance requirements of subpart H of 10 CFR part 71, and with the general provisions of subpart A of 10 CFR 71.

(B) When the isotopic abundance, mass, concentration, degree of irradiation, degree of moderation, or other pertinent property of fissile material in any package is not known, the licensee shall package the fissile material as if the unknown properties have credible values that will cause the maximum neutron multiplication.

120.784: Preliminary Determinations

Prior to the first use of any packaging for the shipment of radioactive material:

(A) The licensee shall ascertain that there are no defects which could significantly reduce the effectiveness of the packaging;

(B) Where the maximum normal operating pressure will exceed 35 kilopascal (five lbf/in^2) gauge, the licensee shall test the containment system at an internal pressure at least 50% higher than the maximum normal operating pressure to verify the capability of that system to maintain its structural integrity at that pressure;

(C) The licensee shall determine that the packaging has been fabricated in accordance with the design approved by the Nuclear Regulatory Commission; and,

(D) The licensee shall conspicuously and durably mark the packaging with its model number, serial number, gross weight, and a package identification number as assigned by the Nuclear Regulatory Commission.

120.785: Routine Determinations

Prior to each shipment of licensed material, the licensee shall determine that:

(A) The package is proper for the contents to be shipped;

(B) The package is in unimpaired physical condition except for superficial defects such as marks or dents;

(C) Each closure device of the packaging, including any required gasket, is properly installed and secured and free of defects;

(D) Any system for containing liquid is adequately sealed and has adequate space or other specified provision for expansion of the liquid;

(E) Any pressure relief device is operable and set in accordance with written procedures;

(F) The package has been loaded and closed in accordance with written procedures;

(G) Any structural part of the package which could be used to lift or tie down the package during transport is rendered inoperable for that purpose unless it satisfies design requirements specified in 10 CFR 71.45;

(H) The level of removable radioactive) contamination on the external surfaces of each package offered for shipment is as low as reasonably achievable.

(1) The level of non-fixed (removable) radioactive contamination may be determined by wiping an area of 300 square centimeters of the surface concerned with an absorbent material, using moderate pressure, and measuring the activity on the wiping material. Sufficient measurements must be taken in the most appropriate locations to yield a representative assessment of the removable contamination levels. Except as provided in 105 CMR 120.785(H)(2), the amount of radioactivity measured on any single wiping material, when averaged over the surface wiped, must not exceed the limits given in 105 CMR 120.785: TABLE III at any time during transport. Other methods of assessment of equal or greater efficiency may be used. When other methods are used, the detection efficiency of the method used must be taken into account and in no case may the removable contamination on the external surfaces of the package exceed ten times the limits listed in 105 CMR 120.785: TABLE III.

(2) In the case of packages transported as exclusive use shipments by rail or highway only, the non-fixed (removable) radioactive contamination at any time during transport must not exceed ten times the levels prescribed in 105 CMR 120.785(H)(1) The levels at the beginning of transport must not exceed the levels in 105 CMR 120.785(H)(1);

TABLE III
NON-FIXED (REMOVABLE EXTERNAL RADIOACTIVE CONTAMINATION - WIPE LIMITS

Contaminant	Maximum Permissible Limits		
	Bq/cm^2	$\mu Ci/cm^2$	dpm/cm^2
Beta and gamma emitters and low toxicity alpha emitters	0.4	10^{-5}	22
All other alpha emitting radionuclides.....	0.04	10^{-6}	2.2

(I) External radiation levels around the package and around the vehicle, if applicable, will not exceed 2 mSv/h (200 millirems per hour) at any point on the external surface of the package at any time during transportation. The transport index shall not exceed 10.0;

120.785: continued

(J) For a package transported in exclusive use by rail, highway or water, radiation levels external to the package may exceed the limits specified in 105 CMR 120.785(A) but shall not exceed any of the following:

(1) 2 mSv/h (200 millirems per hour) on the accessible external surface of the package unless the following conditions are met, in which case the limit is 10 mSv/h (1000 millirems per hour);

(a) The shipment is made in a closed transport vehicle;

(b) Provisions are made to secure the package so that its position within the vehicle remains fixed during transportation; and,

(c) There are no loading or unloading operations between the beginning and end of the transportation.

(2) 2 mSv/h (200 millirems per hour) at any point on the outer surface of the vehicle, including the top and underside of the vehicle, or, in the case of a flat-bed style vehicle, with a personnel barrier, at any point on the vertical planes projected from the outer edges of the vehicle, on the upper surface of the load [or enclosure, if used], and on the lower external surface of the vehicle; A flat-bed style vehicle with a personnel barrier shall have radiation levels determined at vertical planes. If no personnel barrier is in place, the package cannot exceed 2 mSv/h (200 millirems per hour) at any accessible surface;

(3) 0.1 mSv/h (ten millirems per hour) at any point two meters from the vertical planes represented by the outer lateral surfaces of the vehicle, or, in the case of a flat-bed style vehicle, at any point two meters from the vertical planes projected from the outer edges of the vehicle; and,

(4) 0.02 mSv/h (two millirems per hour) in any normally occupied positions of the vehicle, except that this provision does not apply to private motor carriers when persons occupying these positions are provided with special health supervision, personnel radiation exposure monitoring devices, and training in accordance with 105 CMR 120.753; and,

(K) A package must be prepared for transport so that in still air at 100EF (38EC) and in the shade, no accessible surface of a package would have a temperature exceeding 122EF (50EC) in a nonexclusive use shipment or 185EF (85EC) in an exclusive use shipment. Accessible package surface temperatures shall not exceed these limits at any time during transportation.

(L) A package may not incorporate a feature intended to allow continuous venting during transport.

120.786: Air Transport of Plutonium

Notwithstanding the provisions of any general licenses and notwithstanding any exemptions stated directly in 105 CMR 120.770 or included indirectly by citation of the U.S. Department of Transportation regulations, as may be applicable, the licensee shall assure that plutonium in any form is not transported by air, or delivered to a carrier for air transport, unless:

(A) The plutonium is contained in a medical device designed for individual human application;

(B) The plutonium is contained in a material in which the specific activity is not greater than 70 Bq/gm (0.002 microcuries per gram) of material and in which the radioactivity is essentially uniformly distributed;

(C) The plutonium is shipped in a single package containing no more than an A_2 quantity of plutonium in any isotope or form and is shipped in accordance with 105 CMR 120.775; or,

(D) The plutonium is shipped in a package specifically authorized (in the Certificate of Compliance issued by the Nuclear Regulatory Commission for that package) for the shipment of plutonium by air and the licensee requires, through special arrangement with the carrier, compliance with 49 CFR 175.704, the U.S. Department of Transportation regulations applicable to the air transport of plutonium.

120.787A: Opening Instructions

Before delivery of a package to a carrier for transport, the licensee shall ensure that any special instructions needed to safely open the package have been sent to, or otherwise made available to, the consignee for the consignee's use in accordance with 105 CMR 120.246(E).

120.787: Shipment Records

Each licensee shall maintain for a period of three years after shipment a record of each shipment of licensed material not exempt under 105 CMR 120.774, showing, where applicable:

(A) Identification of the packaging by model number and serial number;

(B) Verification that the packaging, as shipped, had no significant defects;

(C) Volume and identification of coolant;

(D) Type and quantity of licensed material in each package, and the total quantity of each shipment;

(E) Date of the shipment;

(F) Name and address of the transferee;

(G) Address to which the shipment was made; and,

(H) Results of the determinations required by 105 CMR 120.785 and by the conditions of the package approval.

120.788: Reports

The licensee shall report to the Agency within 30 days:

(A) Any instance in which there is significant reduction in the effectiveness of any packaging during use;

(B) Details of any defects with safety significance in the packaging after first use, with the means employed to repair the defects and prevent their recurrence; or,

(C) Instances in which the conditions of approval in the certificate of compliance were not observed in making a shipment.

120.789: Advance Notification of Transport of Nuclear Waste

(A) Prior to the transport of any nuclear waste outside of the confines of the licensee's facility or other place of use or storage, or prior to the delivery of any nuclear waste to a carrier for transport, each licensee shall provide advance notification of such transport to the governor, or governor's designee, of each state within or through which the waste will be transported. A list of the mailing addresses of the governors and governors' designees is available upon request from the U.S. Nuclear Regulatory Commission, Document Control Desk, P1-37, Washington, D.C. 20555 Attn: Director, OSP. The list will be published annually in the Federal Register on or about June 30 to reflect any changes in information.

(B) Advance notification is required only when:
(1) The nuclear waste is required to be in Type B packaging for transportation;
(2) The nuclear waste is being transported into, within, or through a state en route to a disposal facility or to a collection point for transport to a disposal facility; and,

120.789: continued

(3) The quantity of licensed material in a single package exceeds:
(a) 3000 times the A_1 value of the radionuclides as specified in 105 CMR 120.795: *Appendix A*, Table A-1 for special form radioactive material;
(b) 3000 times the A_2 value of the radionuclides as specified in 105 CMR 120.795: *Appendix A*, Table A-1 for normal form radioactive material; or,
(c) 1000 TBq (27,000 Ci).

(C) Each advance notification required by 105 CMR 120.789(A) shall contain the following information:
(1) The name, address, and telephone number of the shipper, carrier, and receiver of the shipment;
(2) A description of the nuclear waste contained in the shipment as required by 49 CFR 172.202 and 172.203(d);
(3) The point of origin of the shipment and the seven-day period during which departure of the shipment is estimated to occur;
(4) The seven-day period during which arrival of the shipment at state boundaries is estimated to occur;
(5) The destination of the shipment, and the seven-day period during which arrival of the shipment is estimated to occur; and,
(6) A point of contact with a telephone number for current shipment information.

(D) The notification required by 105 CMR 120.789(A) shall be made in writing to the office of each appropriate governor, or governor's designee, and to the Agency. A notification delivered by mail must be postmarked at least seven days before the beginning of the seven-day period during which departure of the shipment is estimated to occur. A notification delivered by messenger must reach the office of the governor, or governor's designee, at least four days before the beginning of the seven-day period during which departure of the shipment is estimated to occur. A copy of the notification shall be retained by the licensee for three year.

(E) The licensee shall notify each appropriate governor, or governor's designee, and the Agency of any changes to schedule information provided pursuant to 105 CMR 120.789(A) Such notification shall be by telephone to a responsible individual in the office of the governor, or governor's designee, of the appropriate state or states. The licensee shall maintain for three year a record of the name of the individual contacted.

(F) Each licensee who cancels a nuclear waste shipment, for which advance notification has been sent, shall send a cancellation notice, identifying the advance notification that is being cancelled, to the governor, or governor's designee, of each appropriate state and to the Agency. A copy of the notice shall be retained by the licensee for three year.

QUALITY ASSURANCE

120.790: Quality Assurance Requirements

(A) Unless otherwise authorized by the Agency, each licensee shall establish, maintain, and execute a quality assurance program to verify by procedures such as checking, auditing, and inspection that deficiencies, deviations, and defective material and equipment relating to the shipment of packages containing radioactive material are promptly identified and corrected.

(B) The licensee shall identify the material and components to be covered by the quality assurance program.

(C) Each licensee shall document the quality assurance program by written procedures or instructions and shall carry out the program in accordance with those procedures throughout the period during which packaging is used.

(D) Prior to the use of any package for the shipment of radioactive material, each licensee shall obtain approval by the Agency of its quality assurance program.

120.790: continued

(E) The licensee shall maintain sufficient written records to demonstrate compliance with the quality assurance program. Records of quality assurance pertaining to the use of a package for shipment of radioactive material shall be maintained for a period of three years after shipment.

120.795: Appendix A -- Determination of A_1 and A_2

[Delete and replace all previous narrative and Tables I-IV with the following]

A. Values of A_1 and A_2 for individual radionuclides, which are the bases for many activity limits elsewhere in these regulations are given in Table A-1. The curie (Ci) values specified are obtained by converting from the Terabecquerel (TBq) figure. The curie values are expressed to three significant figures to assure that the difference in the TBq and Ci quantities is one tenth of one percent or less. Where values of A_1 or A_2 are unlimited, it is for radiation control purposes only. For nuclear criticality safety, some materials are subject to controls placed on fissile material.

II. For individual radionuclides whose identities are known, but which are not listed in Table A-1, the determination of the values of A_1 and A_2 requires Department approval, except that the values of A_1 and A_2 in Table A-2 may be used without obtaining Agency approval.

III. In the calculations of A_1 and A_2 for a radionuclide not in Table A-1, a single radioactive decay chain, in which radionuclides are present in their naturally occurring proportions, and in which no daughter nuclide has a half-life either longer than ten days, or longer than that of the parent nuclide, shall be considered as a single radionuclide, and the activity to be taken into account, and the A_1 or A_2 value to be applied shall be those corresponding to the parent nuclide of that chain. In the case of radioactive decay chains in which any daughter nuclide has a half-life either longer than ten days, or greater than that of the parent nuclide, the parent and those daughter nuclides shall be considered as mixtures of different nuclides.

IV. For mixtures of radionuclides whose identities and respective activities are known, the following conditions apply:

(a) For special form radioactive material, the maximum quantity transported in a Type A package:

$$\sum_I \frac{B(I)}{A_1(I)} \text{ less than or equal to } 1$$

(b) For normal form radioactive material, the maximum quantity transported in a Type A package:

$$\sum_I \frac{B(I)}{A_2(I)} \text{ less than or equal to } 1$$

where B(I) is the activity of radionuclide I and $A_1(I)$ and $A_2(I)$ are the A_1 and A_2 values for radionuclide respectively.

Alternatively, an A_1 value for mixtures of special form material may be determined as follows:

$$A_1 \text{ for mixture} = \left(\sum_I \frac{f(I)}{A_1(I)} \right)^{-1}$$

where f(I) is the fraction of activity of nuclide I in the mixture and $A_1(I)$ is the appropriate A_1 value for nuclide I.

An A_2 value for mixtures of normal form material may be determined as follows:

$$A_2 \text{ for mixture} = \left(\sum_I \frac{f(I)}{A_2(I)} \right)^{-1}$$

120.795: continued

where f(I) is the fraction of activity of nuclide I in the mixture and $A_2(I)$ is the appropriate A_2 value for nuclide I.

V. When the identity of each radionuclide is known, but the individual activities of some of the radionuclides are not known, the radionuclides may be grouped and the lowest A_1 or A_2 value, as appropriate, for the radionuclides in each group may be used in applying the formulas in paragraph IV. Groups may be based on the total alpha activity and the total beta/gamma activity when these are known, using the lowest A_1 or A_2 values for the alpha emitters and beta/gamma emitters.

Table A-1: A_1 and A_2 Values for Radionuclides

Symbol of Radionuclide	Element and Atomic No.	A_1 (TBq)	A_1 (Ci)	A_2 (TBq)	A_2 (Ci)	Specific Activity (TBq/g)	(Ci/g)
Ac-225	Actinium(89)	0.6	16.2	$1x10^{-2}$	0.270	$2.1x10^{3}$	$5.8x10^{4}$
Ac-227		40	1080	$2x10^{-5}$	$5.41x10^{-4}$	2.7	$7.2x10^{1}$
Ac-228		0.6	16.2	0.4	10.8	$8.4x10^{4}$	$2.2x10^{6}$
Ag-105	Silver(47)	2	54.1	2	54.1	$1.1x10^{3}$	$3.0x10^{4}$
Ag-108m		0.6	16.2	0.6	16.2	$9.7x10^{-1}$	$2.6x10^{1}$
Ag-110m		0.4	10.8	0.4	10.8	$1.8x10^{2}$	$4.7x10^{3}$
Ag-111		0.6	16.2	0.5	13.5	$5.8x10^{3}$	$1.6x10^{5}$
Al-26	Aluminum(13)	0.4	10.8	0.4	10.8	$7.0x10^{-4}$	$1.9x10^{-2}$
Am-241	mericium(95)	2	54.1	$2x10^{-4}$	$5.41x10^{-3}$	$1.3x10^{-1}$	3.4
Am-242m		2	54.1	$2x10^{-4}$	$5.41x10^{-3}$	$3.6x10^{-1}$	$1.0x10^{1}$
Am-243		2	54.1	$2x10^{-4}$	$5.41x10^{-3}$	$7.4x10^{-3}$	$2.0x10^{-1}$
Ar-37	Argon(18)	40	1080	40	1080	$3.7x10^{3}$	$9.9x10^{4}$
Ar-39		20	541	20	541	1.3	$3.4x10^{1}$
Ar-41		0.6	16.2	0.6	16.2	$1.5x10^{6}$	$4.2x10^{7}$
Ar-42		0.2	5.41	0.2	5.41	9.6	$2.6x10^{2}$
As-72	Arsenic(33)	0.2	5.41	0.2	5.41	$6.2x10^{4}$	$1.7x10^{6}$
As-73		40	1080	40	1080	$8.2x10^{2}$	$2.2x10^{4}$
As-74		1	27.0	0.5	13.5	$3.7x10^{3}$	$9.9x10^{4}$
As-76		0.2	5.41	0.2	5.41	$5.8x10^{4}$	$1.6x10^{6}$
As-77		20	541	0.5	13.5	$3.9x10^{4}$	$1.0x10^{6}$
At-211	Astatine(85)	30	811	2	54.1	$7.6x10^{4}$	$2.1x10^{6}$
Au-193	Gold(79)	6	162	6	162	$3.4x10^{4}$	$9.2x10^{5}$
Au-194		1	27.0	1	27.0	$1.5x10^{4}$	$4.1x10^{5}$
Au-195		10	270	10	270	$1.4x10^{2}$	$3.7x10^{3}$
Au-196		2	54.1	2	54.1	$4.0x10^{3}$	$1.1x10^{5}$
Au-198		3	81.1	0.5	13.5	$9.0x10^{3}$	$2.4x10^{5}$
Au-199		10	270	0.9	24.3	$7.7x10^{3}$	$2.1x10^{5}$
Ba-131	Barium(56)	2	54.1	2	54.1	$3.1x10^{3}$	$8.4x10^{4}$
Ba-133m		10	270	0.9	24.3	$2.2x10^{4}$	$6.1x10^{5}$
Ba-133		3	81.1	3	81.1	9.4	$2.6x10^{2}$
Ba-140		0.4	10.8	0.4	10.8	$2.7x10^{3}$	$7.3x10^{4}$
Be-7	Beryllium(4)	20	541	20	541	$1.3x10^{4}$	$3.5x10^{5}$
Be-10		20	541	0.5	13.5	$8.3x10^{-4}$	$2.2x10^{-2}$
Bi-205	Bismuth(83)	0.6	16.2	0.6	16.2	$1.5x10^{3}$	$4.2x10^{4}$
Bi-206		0.3	8.11	0.3	8.11	$3.8x10^{3}$	$1.0x10^{5}$
Bi-207		0.7	18.9	0.7	18.9	1.9	$5.2x10^{1}$
Bi-210m		0.3	8.11	$3x10^{-2}$	0.811	$2.1x10^{-5}$	$5.7x10^{-4}$
Bi-210		0.6	16.2	0.5	13.5	$4.6x10^{3}$	$1.2x10^{5}$
Bi-212		0.3	8.11	0.3	8.11	$5.4x10^{5}$	$1.5x10^{7}$
Bk-247	Berkelium(97)	2	54.1	$2x10^{-4}$	$5.41x10^{-3}$	$3.8x10^{-2}$	1.0

120.795: continued

Table A-1: A_1 and A_2 Values for Radionuclides (continued)

Symbol of Radionuclide	Element and Atomic No.	A_1 (TBq)	A_1 (Ci)	A_2 (TBq)	A_2 (Ci)	Specific Activity (TBq/g)	(Ci/g)
Bk-249		40	1080	$8x10^{-2}$	2.16	$6.1x10^{1}$	$1.6x10^{3}$
Br-76	Bromine(35)	0.3	8.11	0.3	8.11	$9.4x10^{4}$	$2.5x10^{6}$
Br-77		3	81.1	3	81.1	$2.6x10^{4}$	$7.1x10^{5}$
Br-82		0.4	10.8	0.4	10.8	$4.0x10^{4}$	$1.1x10^{6}$
C-11	Carbon(6)	1	27	0.5	13.5	$3.1x10^{7}$	$8.4x10^{8}$
C-14		40	1080	2	54.1	$1.6x10^{-1}$	4.5
Ca-41	Calcium(20)	40	1080	40	1080	$3.1x10^{-3}$	$8.5x10^{-2}$
Ca-45		40	1080	0.9	24.3	$6.6x10^{2}$	$1.8x10^{4}$
Ca-47		0.9	24.3	0.5	13.5	$2.3x10^{4}$	$6.1x10^{5}$
Cd-109	Cadmium(48)	40	1080	1	27.0	$9.6x10^{1}$	$2.6x10^{3}$
Cd-113m		20	541	$9x10^{-2}$	2.43	$8.3x10^{4}$	$2.2x10^{2}$
Cd-115m		0.3	8.11	0.3	8.11	$9.4x10^{2}$	$2.5x10^{4}$
Cd-115		4	108	0.5	13.5	$1.9x10^{4}$	$5.1x10^{5}$
Ce-139	Cerium(58)	6	162	6	162	$2.5x10^{2}$	$6.8x10^{3}$
Ce-141		10	270	0.5	13.5	$1.1x10^{3}$	$2.8x10^{4}$
Ce-143		0.6	16.2	0.5	13.5	$2.5x10^{4}$	$6.6x10^{5}$
Ce-144		0.2	5.41	0.2	5.41	$1.2x10^{2}$	$3.2x10^{3}$
Cf-248	Californium(98)	30	811	$3x10^{-3}$	$8.11x10^{-2}$	$5.8x10^{1}$	$1.6x10^{3}$
Cf-249		2	54.1	$2x10^{-4}$	$5.41x10^{-3}$	$1.5x10^{-1}$	4.1
Cf-250		5	135	$5x10^{-4}$	$1.35x10^{-2}$	4.0	$1.1x10^{2}$
Cf-251		2	54.1	$2x10^{-4}$	$5.41x10^{-3}$	$5.9x10^{-2}$	1.6
Cf-252		0.1	2.70	$1x10^{-3}$	$2.70x10^{-2}$	$2.0x10^{1}$	$5.4x10^{2}$
Cf-253		40	1080	$6x10^{-2}$	1.62	$1.1x10^{3}$	$2.9x10^{4}$
Cf-254		$3x10^{-3}$	$8.11x10^{-2}$	$6x10^{-4}$	$1.62x10^{-2}$	$3.1x10^{2}$	$8.5x10^{3}$
Cl-36	Chlorine(17)	20	541	0.5	13.5	$1.2x10^{-3}$	$3.3x10^{-2}$
Cl-38		0.2	5.41	0.2	5.41	$4.9x10^{6}$	$1.3x10^{8}$
Cm-240	Curium(96)	40	1080	$2x10^{-2}$	0.541	$7.5x10^{2}$	$2.0x10^{4}$
Cm-241		2	54.1	0.9	24.3	$6.1x10^{2}$	$1.7x10^{4}$
Cm-242		40	1080	$1x10^{-2}$	0.270	$1.2x10^{2}$	$3.3x10^{3}$
Cm-243		3	81.1	$3x10^{-4}$	$8.11x10^{-3}$	1.9	$5.2x10^{1}$
Cm-244		4	108	$4x10^{-4}$	$1.08x10^{-2}$	3.0	$8.1x10^{5}$
Cm-245		2	54.1	$2x10^{-4}$	$5.41x10^{-3}$	$6.4x10^{-3}$	$1.7x10^{-1}$
Cm-246		2	54.1	$2x10^{-4}$	$5.41x10^{-3}$	$1.1x10^{-2}$	$3.1x10^{-1}$
Cm-247		2	54.1	$2x10^{-4}$	$5.41x10^{-3}$	$3.4x10^{-6}$	$9.3x10^{-5}$
Cm-248		$4x10^{-2}$	1.08	$5x10^{-5}$	$1.35x10^{-3}$	$1.6x10^{-4}$	$4.2x10^{-3}$
Co-55	Cobalt(27)	0.5	13.5	0.5	13.5	$1.1x10^{5}$	$3.1x10^{6}$
Co-56		0.3	8.11	0.3	8.11	$1.1x10^{3}$	$3.0x10^{4}$
Co-57		8	216	8	216	$3.1x10^{2}$	$8.4x10^{3}$
Co-58m		40	1080	40	1080	$2.2x10^{5}$	$5.9x10^{6}$
Co-58		1	27.0	1	27.0	$1.2x10^{3}$	$3.2x10^{4}$
Co-60		0.4	10.8	0.4	10.8	$4.2x10^{1}$	$1.1x10^{3}$
Cr-51	Chromium(24)	30	811	30	811	$3.4x10^{3}$	$9.2x10^{4}$
Cs-129	Cesium(55)	4	108	4	108	$2.8x10^{4}$	$7.6x10^{5}$
Cs-131		40	1080	40	1080	$3.8x10^{3}$	$1.0x10^{5}$
Cs-132		1	27.0	1	27.0	$5.7x10^{3}$	$1.5x10^{5}$

120.795: continued

Table A-1: A_1 and A_2 Values for Radionuclides (continued)

Symbol of Radionuclide	Element and Atomic No.	A_1 (TBq)	A_1 (Ci)	A_2 (TBq)	A_2 (Ci)	Specific Activity (TBq/g)	Specific Activity (Ci/g)
Cs-134m		40	1080	9	243	$3.0x10^5$	$8.0x10^6$
Cs-134		0.6	16.2	0.5	13.5	$4.8x10^1$	$1.3x10^3$
Cs-135		40	1080	0.9	24.3	$4.3x10^{-5}$	$1.2x10^{-3}$
Cs-136		0.5	13.5	0.5	13.5	$2.7x10^3$	$7.3x10^4$
Cs-137		2	54.1	0.5	13.5	3.2	$8.7x10^1$
Cu-64	Copper(29)	5	135	0.9	24.3	$1.4x10^5$	$3.9x10^6$
Cu-67		9	243	0.9	24.3	$2.8x10^4$	$7.6x10^5$
Dy-159	Dysprosium(66)	20	541	20	541	$2.1x10^2$	$5.7x10^3$
Dy-165		0.6	16.2	0.5	13.5	$3.0x10^5$	$8.2x10^6$
Dy-166		0.3	8.11	0.3	8.11	$8.6x10^3$	$2.3x10^5$
Er-169	Erbium(68)	40	1080	0.9	24.3	$3.1x10^3$	$8.3x10^4$
Er-171		0.6	16.2	0.5	13.5	$9.0x10^4$	$2.4x10^6$
Es-253	Einsteinium(99)[a]	200	5400	$2.1x10^{-2}$	$5.4x10^{-1}$	--	--
Es-254		30	811	$3x10^{-3}$	$8.11x10^{-2}$	--	--
Es-254m		0.6	16.2	0.4	10.8	--	--
Es-255		--	--	--	--	--	--
Eu-147	Europium(63)	2	54.1	2	54.1	$1.4x10^3$	$3.7x10^4$
Eu-148		0.5	13.5	0.5	13.5	$6.0x10^2$	$1.6x10^4$
Eu-149		20	541	20	541	$3.5x10^2$	$9.4x10^3$
Eu-150		0.7	18.9	0.7	18.9	$6.1x10^4$	$1.6x10^6$
Eu-152m		0.6	16.2	0.5	13.5	$8.2x10^4$	$2.2x10^6$
Eu-152		0.9	24.3	0.9	24.3	6.5	$1.8x10^2$
Eu-154		0.8	21.6	0.5	13.5	9.8	$2.6x10^2$
Eu-155		20	541	2	54.1	$1.8x10^1$	$4.9x10^2$
Eu-156		0.6	16.2	0.5	13.5	$2.0x10^3$	$5.5x10^4$
F-18	Fluorine(9)	1	27.0	0.5	13.5	$3.5x10^6$	$9.5x10^7$
Fe-52	Iron(26)	0.2	5.41	0.2	5.41	$2.7x10^5$	$7.3x10^6$
Fe-55		40	1080	40	1080	$8.8x10^1$	$2.4x10^3$
Fe-59		0.8	21.6	0.8	21.6	$1.8x10^3$	$5.0x10^4$
Fe-60		40	1080	0.2	5.41	$7.4x10^{-4}$	$2.0x10^{-2}$
Fm-255	Fermium(100)[b]	40	1080	0.8	21.6	--	--
Fm-257		10	270	$8x10^{-3}$	$21.6x10^{-1}$	--	--
Ga-67	Gallium(31)	6	162	6	162	$2.2x10^4$	$6.0x10^5$
Ga-68		0.3	8.11	0.3	8.11	$1.5x10^6$	$4.1x10^7$
Ga-72		0.4	10.8	0.4	10.8	$1.1x10^5$	$3.1x10^6$
Gd-146	Gadolinium(64)	0.4	10.8	0.4	10.8	$6.9x10^2$	$1.9x10^4$
Gd-148		3	81.1	$3x10^{-4}$	$8.11x10^{-3}$	1.2	$3.2x10^1$
Gd-153		10	270	5	135	$1.3x10^2$	$3.5x10^3$
Gd-159		4	108	0.5	13.5	$3.9x10^4$	$1.1x10^6$
Ge-68	Germanium(32)	0.3	8.11	0.3	8.11	$2.6x10^2$	$7.1x10^3$
Ge-71		40	1080	40	1080	$5.8x10^3$	$1.6x10^5$
Ge-77		0.3	8.11	0.3	8.11	$1.3x10^5$	$3.6x10^6$
H-3	Hydrogen(1)	See T-Tritium					
Hf-172	Hafnium(72)	0.5	13.5	0.3	8.11	$4.1x10^1$	$1.1x10^3$

[a]International shipments of Einsteinium require multilateral approval of A_1 and A_2 values.

120.795: continued

Table A-1: A_1 and A_2 Values for Radionuclides (continued)

Symbol of Radionuclide	Element and Atomic No.	A_1 (TBq)	A_1 (Ci)	A_2 (TBq)	A_2 (Ci)	Specific Activity (TBq/g)	(Ci/g)
Hf-175		3	81.1	3	81.1	3.9×10^{2}	1.1×10^{4}
Hf-181		2	54.1	0.9	24.3	6.3×10^{2}	1.7×10^{4}
Hf-182		4	108	3×10^{-2}	0.811	8.1×10^{-6}	2.2×10^{-4}
Hg-194	Mercury(80)	1	27.0	1	27.0	1.3×10^{-1}	3.5
Hg-195m		5	135	5	135	1.5×10^{4}	4.0×10^{5}
Hg-197m		10	270	0.9	24.3	2.5×10^{4}	6.7×10^{5}
Hg-197		10	270	10	270	9.2×10^{3}	2.5×10^{5}
Hg-203		4	108	0.9	24.3	5.1×10^{2}	1.4×10^{4}
Ho-163	Holmium(67)	40	1080	40	1080	2.7	7.6×10^{1}
Ho-166m		0.6	16.2	0.3	8.11	6.6×10^{-2}	1.8
Ho-166		0.3	8.11	0.3	8.11	2.6×10^{4}	7.0×10^{5}
I-123	Iodine(53)	6	162	6	162	7.1×10^{4}	1.9×10^{6}
I-124		0.9	24.3	0.9	24.3	9.3×10^{3}	2.5×10^{5}
I-125		20	541	2	54.1	6.4×10^{2}	1.7×10^{4}
I-126		2	54.1	0.9	24.3	2.9×10^{3}	8.0×10^{4}
I-129		Unlimited	Unlimited	Unlimited	Unlimited	6.5×10^{-6}	1.8×10^{-4}
I-131		3	81.1	0.5	13.5	4.6×10^{3}	1.2×10^{5}
I-132		0.4	10.8	0.4	10.8	3.8×10^{5}	1.0×10^{7}
I-133		0.6	16.2	0.5	13.5	4.2×10^{4}	1.1×10^{6}
I-134		0.3	8.11	0.3	8.11	9.9×10^{5}	2.7×10^{7}
I-135		0.6	16.2	0.5	13.5	1.3×10^{5}	3.5×10^{6}
In-111	Indium(49)	2	54.1	2	54.1	1.5×10^{4}	4.2×10^{5}
In-113m		4	108	4	108	6.2×10^{5}	1.7×10^{7}
In-114m		0.3	8.11	0.3	8.11	8.6×10^{2}	2.3×10^{4}
In-115m		6	162	0.9	24.3	2.2×10^{5}	6.1×10^{6}
Ir-189	Iridium(77)	10	270	10	270	1.9×10^{3}	5.2×10^{4}
Ir-190		0.7	18.9	0.7	18.9	2.3×10^{3}	6.2×10^{4}
Ir-192		1	27.0	0.5	13.5	3.4×10^{2}	9.2×10^{3}
Ir-193m		10	270	10	270	2.4×10^{3}	6.4×10^{4}
Ir-194		0.2	5.41	0.2	5.41	3.1×10^{4}	8.4×10^{5}
K-40	Potassium(19)	0.6	16.2	0.6	16.2	2.4×10^{-7}	6.4×10^{-6}
K-42		0.2	5.41	0.2	5.41	2.2×10^{5}	6.0×10^{6}
K-43		1.0	27.0	0.5	13.5	1.2×10^{5}	3.3×10^{6}
Kr-81	Krypton(36)	40	1080	40	1080	7.8×10^{-4}	2.1×10^{-2}
Kr-85m		6	162	6	162	3.0×10^{5}	8.2×10^{6}
Kr-85		20	541	10	270	1.5×10^{1}	3.9×10^{2}
Kr-87		0.2	5.41	0.2	5.41	1.0×10^{6}	2.8×10^{7}
La-137	Lanthanum(57)	40	1080	2	54.1	1.6×10^{-3}	4.4×10^{-2}
La-140		0.4	10.8	0.4	10.8	2.1×10^{4}	5.6×10^{5}
Lu-172	Lutetium(71)	0.5	13.5	0.5	13.5	4.2×10^{3}	1.1×10^{5}
Lu-173		8	216	8	216	5.6×10^{1}	1.5×10^{3}
Lu-174m		20	541	8	216	2.0×10^{2}	5.3×10^{3}
Lu-174		8	216	4	108	2.3×10^{1}	6.2×10^{2}
Lu-177		30	811	0.9	24.3	4.1×10^{3}	1.1×10^{5}

[b]International shipments of Fermium require multilateral approval of A_1 and A_2 values.

120.795: continued

Table A-1: A_1 and A_2 Values for Radionuclides (continued)

Symbol of Radionuclide	Element and Atomic No.	A_1 (TBq)	A_1 (Ci)	A_2 (TBq)	A_2 (Ci)	Specific Activity (TBq/g)	(Ci/g)
MFP	For mixed fission products, use formula for mixtures or Table A-2.						
Mg-28	Magnesium(12)	0.2	5.41	0.2	5.41	$2.0x10^{5}$	$5.4x10^{6}$
Mn-52	Manganese(25)	0.3	8.11	0.3	8.11	$1.6x10^{4}$	$4.4x10^{5}$
Mn-53		Unlimited	Unlimited	Unlimited	Unlimited	$6.8x10^{-5}$	$1.8x10^{-3}$
Mn-54		1	27.0	1	27.0	$2.9x10^{2}$	$7.7x10^{3}$
Mn-56		0.2	5.41	0.2	5.41	$8.0x10^{5}$	$2.2x10^{7}$
Mo-93	Molybdenum(42)	40	1080	7	189	$4.1x10^{-2}$	1.1
Mo-99		0.6	16.2	0.5	13.5[c]	$1.8x10^{4}$	$4.8x10^{5}$
N-13	Nitrogen(7)	0.6	16.2	0.5	13.5	$5.4x10^{7}$	$1.5x10^{9}$
Na-22	Sodium(11)	0.5	13.5	0.5	13.5	$2.3x10^{2}$	$6.3x10^{3}$
Na-24		0.2	5.41	0.2	5.41	$3.2x10^{5}$	$8.7x10^{6}$
Nb-92m	Niobium(41)	0.7	18.9	0.7	18.9	$5.2x10^{3}$	$1.4x10^{5}$
Nb-93m		40	1080	6	162	8.8	$2.4x10^{2}$
Nb-94		0.6	16.2	0.6	16.2	$6.9x10^{-3}$	$1.9x10^{-1}$
Nb-95		1	27.0	1	27.0	$1.5x10^{3}$	$3.9x10^{4}$
Nb-97		0.6	16.2	0.5	13.5	$9.9x10^{5}$	$2.7x10^{7}$
Nd-147	Neodymium(60)	4	108	0.5	13.5	$3.0x10^{3}$	$8.1x10^{4}$
Nd-149		0.6	16.2	0.5	13.5	$4.5x10^{5}$	$1.2x10^{7}$
Ni-59	Nickel(28)	40	1080	40	1080	$3.0x10^{-3}$	$8.0x10^{-2}$
Ni-63		40	1080	30	811	2.1	$5.7x10^{1}$
Ni-65		0.3	8.11	0.3	8.11	$7.1x10^{5}$	$1.9x10^{7}$
Np-235	Neptunium(93)	40	1080	40	1080	$5.2x10^{1}$	$1.4x10^{3}$
Np-236		7	189	$1x10^{-3}$	$2.70x10^{-2}$	$4.7x10^{-4}$	$1.3x10^{-2}$
Np-237		2	54.1	$2x10^{-4}$	$5.41x10^{-3}$	$2.6x10^{-5}$	$7.1x10^{-4}$
Np-239		6	162	0.5	13.5	$8.6x10^{3}$	$2.3x10^{5}$
Os-185	Osmium(76)	1	27.0	1	27.0	$2.8x10^{2}$	$7.5x10^{3}$
Os-191m		40	1080	40	1080	$4.6x10^{4}$	$1.3x10^{6}$
Os-191		10	270	0.9	24.3	$1.6x10^{3}$	$4.4x10^{4}$
Os-193		0.6	16.2	0.5	13.5	$2.0x10^{4}$	$5.3x10^{5}$
Os-194		0.2	5.41	0.2	5.41	$1.1x10^{1}$	$3.1x10^{2}$
P-32	Phosphorus(15)	0.3	8.11	0.3	8.11	$1.1x10^{4}$	$2.9x10^{5}$
P-33		40	1080	0.9	24.3	$5.8x10^{3}$	$1.6x10^{5}$
Pa-230	Protactinium(91)	2	54.1	0.1	2.70	$1.2x10^{3}$	$3.3x10^{4}$
Pa-231		0.6	16.2	$6x10^{-5}$	$1.62x10^{-3}$	$1.7x10^{-3}$	$4.7x10^{-2}$
Pa-233		5	135	0.9	24.3	$7.7x10^{2}$	$2.1x10^{4}$
Pb-201	Lead(82)	1	27.0	1	27.0	$6.2x10^{4}$	$1.7x10^{6}$
Pb-202		40	1080	2	54.1	$1.2x10^{-4}$	$3.4x10^{-3}$
Pb-203		3	81.1	3	81.1	$1.1x10^{4}$	$3.0x10^{5}$
Pb-205		Unlimited	Unlimited	Unlimited	Unlimited	$4.5x10^{-6}$	$1.2x10^{-4}$
Pb-210		0.6	16.2	$9x10^{-3}$	0.243	2.8	$7.6x10^{1}$
Pb-212		0.3	8.11	0.3	8.11	$5.1x10^{4}$	$1.4x10^{6}$
Pd-103	Palladium(46)	40	1080	40	1080	$2.8x10^{3}$	$7.5x10^{4}$
Pd-107		Unlimited	Unlimited	Unlimited	Unlimited	$1.9x10^{-5}$	$5.1x10^{-4}$
Pd-109		0.6	16.2	0.5	13.5	$7.9x10^{4}$	$2.1x10^{6}$
Pm-143	Promethium(61)	3	81.1	3	81.1	$1.3x10^{2}$	$3.4x10^{3}$

[c]20 Ci for Mo^{99} for domestic use.

120.795: continued

Table A-1: A_1 and A_2 Values for Radionuclides (continued)

Symbol of Radionuclide	Element and Atomic No.	A_1 (TBq)	A_1 (Ci)	A_2 (TBq)	A_2 (Ci)	Specific Activity (TBq/g)	(Ci/g)
Pm-144		0.6	16.2	0.6	16.2	$9.2x10^{1}$	$2.5x10^{3}$
Pm-145		30	811	7	189	5.2	$1.4x10^{2}$
Pm-147		40	1080	0.9	24.3	$3.4x10^{1}$	$9.3x10^{2}$
Pm-148m		0.5	13.5	0.5	13.5	$7.9x10^{2}$	$2.1x10^{4}$
Pm-149		0.6	16.2	0.5	13.5	$1.5x10^{4}$	$4.0x10^{5}$
Pm-151		3	81.1	0.5	13.5	$2.7x10^{4}$	$7.3x10^{5}$
Po-208	Polonium(84)	40	1080	$2x10^{-2}$	0.541	$2.2x10^{1}$	$5.9x10^{2}$
Po-209		40	1080	$2x10^{-2}$	0.541	$6.2x10^{-1}$	$1.7x10^{1}$
Po-210		40	1080	$2x10^{-2}$	0.541	$1.7x10^{2}$	$4.5x10^{3}$
Pr-142	Praseodymium(59)		0.2	5.41	0.2	5.41	4 . 3 x 1 0 [4]
	$1.2x10^{6}$						
Pr-143		4	108	0.5	13.5	$2.5x10^{3}$	$6.7x10^{4}$
Pt-188	Platinum(78)	0.6	16.2	0.6	16.2	$2.5x10^{3}$	$6.8x10^{4}$
Pt-191		3	81.1	3	81.1	$8.7x10^{3}$	$2.4x10^{5}$
Pt-193m		40	1080	9	243	$5.8x10^{3}$	$1.6x10^{5}$
Pt-193		40	1080	40	1080	1.4	$3.7x10^{1}$
Pt-195m		10	270	2	54.1	$6.2x10^{3}$	$1.7x10^{5}$
Pt-197m		10	270	0.9	24.3	$3.7x10^{5}$	$1.0x10^{7}$
Pt-197		20	541	0.5	13.5	$3.2x10^{4}$	$8.7x10^{5}$
Pu-236	Plutonium(94)	7	189	$7x10^{-4}$	$1.89x10^{-2}$	$2.0x10^{1}$	$5.3x10^{2}$
Pu-237		20	541	20	541	$4.5x10^{2}$	$1.2x10^{4}$
Pu-238		2	54.1	$2x10^{-4}$	$5.41x10^{-3}$	$6.3x10^{-1}$	$1.7x10^{1}$
Pu-239		2	54.1	$2x10^{-4}$	$5.41x10^{-3}$	$2.3x10^{-3}$	$6.2x10^{-2}$
Pu-240		2	54.1	$2x10^{-4}$	$5.41x10^{-3}$	$8.4x10^{-3}$	$2.3x10^{-1}$
Pu-241		40	1080	$1x10^{-2}$	0.270	3.8	$1.0x10^{2}$
Pu-242		2	54.1	$2x10^{-4}$	$5.41x10^{-3}$	$1.5x10^{-4}$	$3.9x10^{-3}$
Pu-244		0.3	8.11	$2x10^{-4}$	$5.41x10^{-3}$	$6.7x10^{-7}$	$1.8x10^{-5}$
Ra-223	Radium(88)	0.6	16.2	$3x10^{-2}$	0.811	$1.9x10^{3}$	$5.1x10^{4}$
Ra-224		0.3	8.11	$6x10^{-2}$	1.62	$5.9x10^{3}$	$1.6x10^{5}$
Ra-225		0.6	16.2	$2x10^{-2}$	0.541	$1.5x10^{3}$	$3.9x10^{4}$
Ra-226		0.3	8.11	$2x10^{-2}$	0.541	$3.7x10^{-2}$	1.0
Ra-228		0.6	16.2	$4x10^{-2}$	1.08	$1.0x10^{1}$	$2.7x10^{2}$
Rb-81	Rubidium(37)	2	54.1	0.9	24.3	$3.1x10^{5}$	$8.4x10^{6}$
Rb-83		2	54.1	2	54.1	$6.8x10^{2}$	$1.8x10^{4}$
Rb-84		1	27.0	0.9	24.3	$1.8x10^{3}$	$4.7x10^{4}$
Rb-86		0.3	8.11	0.3	8.11	$3.0x10^{3}$	$8.1x10^{4}$
Rb-87		Unlimited	Unlimited	Unlimited	Unlimited	$3.2x10^{-9}$	$8.6x10^{-8}$
Rb (natural)		Unlimited	Unlimited	Unlimited	Unlimited	$6.7x10^{6}$	$1.8x10^{8}$
Re-183	Rhenium(75)	5	135	5	135	$3.8x10^{2}$	$1.0x10^{4}$
Re-184m		3	81.1	3	81.1	$1.6x10^{2}$	$4.3x10^{3}$
Re-184		1	27.0	1	27.0	$6.9x10^{2}$	$1.9x10^{4}$
Re-186		4	108	0.5	13.5	$6.9x10^{3}$	$1.9x10^{5}$
Re-187		Unlimited	Unlimited	Unlimited	Unlimited	$1.4x10^{-9}$	$3.8x10^{-8}$
Re-188		0.2	5.41	0.2	5.41	$3.6x10^{4}$	$9.8x10^{5}$

120.795: continued

Table A-1: A_1 and A_2 Values for Radionuclides (continued)

Symbol of Radionuclide	Element and Atomic No.	A_1 (TBq)	A_1 (Ci)	A_2 (TBq)	A_2 (Ci)	Specific Activity (TBq/g)	(Ci/g)
Re-189		4	108	0.5	13.5	$2.5x10^4$	$6.8x10^5$
Re (natural)		Unlimited	Unlimited	Unlimited	Unlimited	--	$2.4x10^{-8}$
Rh-99	Rhodium(45)	2	54.1	2	54.1	$3.0x10^3$	$8.2x10^4$
Rh-101		4	108	4	108	$4.1x10^1$	$1.1x10^3$
Rh-102m		2	54.1	0.9	24.3	$2.3x10^2$	$6.2x10^3$
Rh-102		0.5	13.5	0.5	13.5	$4.5x10^1$	$1.2x10^3$
Rh-103m		40	1080	40	1080	$1.2x10^6$	$3.3x10^7$
Rh-105		10	270	0.9	24.3	$3.1x10^4$	$8.4x10^5$
Rn-222	Radon(86)	0.2	5.41	$4x10^{-3}$	0.108	$5.7x10^3$	$1.5x10^5$
Ru-97	Ruthenium(44)	4	108	4	108	$1.7x10^4$	$4.6x10^5$
Ru-103		2	54.1	0.9	24.3	$1.2x10^3$	$3.2x10^4$
Ru-105		0.6	16.2	0.5	13.5	$2.5x10^5$	$6.7x10^6$
Ru-106		0.2	5.41	0.2	5.41	$1.2x10^2$	$3.3x10^3$
S-35	Sulfur(16)	40	1080	2	54.1	$1.6x10^3$	$4.3x10^4$
Sb-122	Antimony(51)	0.3	8.11	0.3	8.11	$1.5x10^4$	$4.0x10^5$
Sb-124		0.6	16.2	0.5	13.5	$6.5x10^2$	$1.7x10^4$
Sb-125		2	54.1	0.9	24.3	$3.9x10^1$	$1.0x10^3$
Sb-126		0.4	10.8	0.4	10.8	$3.1x10^3$	$8.4x10^4$
Sc-44	Scandium(21)	0.5	13.5	0.5	13.5	$6.7x10^5$	$1.8x10^7$
Sc-46		0.5	13.5	0.5	13.5	$1.3x10^3$	$3.4x10^4$
Sc-47		9	243	0.9	24.3	$3.1x10^4$	$8.3x10^5$
Sc-48		0.3	8.11	0.3	8.11	$5.5x10^4$	$1.5x10^6$
Se-75	Selenium(34)	3	81.1	3	81.1	$5.4x10^2$	$1.5x10^4$
Se-79		40	1080	2	54.1	$2.6x10^{-3}$	$7.0x10^{-2}$
Si-31	Silicon(14)	0.6	16.2	0.5	13.5	$1.4x10^6$	$3.9x10^7$
Si-32		40	1080	0.2	5.41	3.9	$1.1x10^2$
Sm-145	Samarium(62)	20	541	20	541	$9.8x10^1$	$2.6x10^3$
Sm-147		Unlimited	Unlimited	Unlimited	Unlimited	$8.5x10^{-1}0$	$2.3x10^{-8}$
Sm-151		40	1080	4	108	$9.7x10^{-1}$	$2.6x10^1$
Sm-153		4	108	0.5	13.5	$1.6x10^4$	$4.4x10^5$
Sn-113	Tin(50)	4	108	4	108	$3.7x10^2$	$1.0x10^4$
Sn-117m		6	162	2	54.1	$3.0x10^3$	$8.2x10^4$
Sn-119m		40	1080	40	1080	$1.4x10^2$	$3.7x10^3$
Sn-121m		40	1080	0.9	24.3	2.0	$5.4x10^1$
Sn-123		0.6	16.2	0.5	13.5	$3.0x10^2$	$8.2x10^3$
Sn-125		0.2	5.41	0.2	5.41	$4.0x10^3$	$1.1x10^5$
Sn-126		0.3	8.11	0.3	8.11	$1.0x10^{-3}$	$2.8x10^{-2}$
Sr-82	Strontium(38)	0.2	5.41	0.2	5.41	$2.3x10^3$	$6.2x10^4$
Sr-85m		5	135	5	135	$1.2x10^6$	$3.3x10^7$
Sr-85		2	54.1	2	54.1	$8.8x10^2$	$2.4x10^4$
Sr-87m		3	81.1	3	81.1	$4.8x10^5$	$1.3x10^7$
Sr-89		0.6	16.2	0.5	13.5	$1.1x10^3$	$2.9x10^4$
Sr-90		0.2	5.41	0.1	2.70	5.1	$1.4x10^2$
Sr-91		0.3	8.11	0.3	8.11	$1.3x10^5$	$3.6x10^6$
Sr-92		0.8	21.6	0.5	13.5	$4.7x10^5$	$1.3x10^7$

120.795: continued

Table A-1: A_1 and A_2 Values for Radionuclides (continued)

Symbol of Radionuclide	Element and Atomic No.	A_1 (TBq)	A_1 (Ci)	A_2 (TBq)	A_2 (Ci)	Specific Activity (TBq/g)	(Ci/g)
T	Tritium(1)	40	1080	40	1080	$3.6x10^{2}$	$9.7x10^{3}$
Ta-178	Tantalum(73)	1	27.0	1	27.0	$4.2x10^{6}$	$1.1x10^{8}$
Ta-179		30	811	30	811	$4.1x10^{1}$	$1.1x10^{3}$
Ta-182		0.8	21.6	0.5	13.5	$2.3x10^{2}$	$6.2x10^{3}$
Tb-157	Terbium(65)	40	1080	10	270	$5.6x10^{-1}$	$1.5x10^{1}$
Tb-158		1	27.0	0.7	18.9	$5.6x10^{-1}$	$1.5x10^{1}$
Tb-160		0.9	24.3	0.5	13.5	$4.2x10^{2}$	$1.1x10^{4}$
Tc-95m	Technetium(43)	2	54.1	2	54.1	$8.3x10^{2}$	$2.2x10^{4}$
Tc-96m		0.4	10.8	0.4	10.8	$1.4x10^{6}$	$3.8x10^{7}$
Tc-96		0.4	10.8	0.4	10.8	$1.2x10^{4}$	$3.2x10^{5}$
Tc-97m		40	1080	40	1080	$5.6x10^{2}$	$1.5x10^{4}$
Tc-97		Unlimited	Unlimited	Unlimited	Unlimited	$5.2x10^{-5}$	$1.4x10^{-3}$
Tc-98		0.7	18.9	0.7	18.9	$3.2x10^{-5}$	$8.7x10^{-4}$
Tc-99m		8	216	8	216	$1.9x10^{5}$	$5.3x10^{6}$
Tc-99		40	1080	0.9	24.3	$6.3x10^{-4}$	$1.7x10^{-2}$
Te-118	Tellurium(52)	0.2	5.41	0.2	5.41	$6.8x10^{3}$	$1.8x10^{5}$
Te-121m		5	135	5	135	$2.6x10^{2}$	$7.0x10^{3}$
Te-121		2	54.1	2	54.1	$2.4x10^{3}$	$6.4x10^{4}$
Te-123m		7	189	7	189	$3.3x10^{2}$	$8.9x10^{3}$
Te-125m		30	811	9	243	$6.7x10^{2}$	$1.8x10^{4}$
Te-127m		20	541	0.5	13.5	$3.5x10^{2}$	$9.4x10^{3}$
Te-127		20	541	0.5	13.5	$9.8x10^{4}$	$2.6x10^{6}$
Te-129m		0.6	16.2	0.5	13.5	$1.1x10^{3}$	$3.0x10^{4}$
Te-129		0.6	16.2	0.5	13.5	$7.7x10^{5}$	$2.1x10^{7}$
Te-131m		0.7	18.9	0.5	13.5	$3.0x10^{4}$	$8.0x10^{5}$
Te-132		0.4	10.8	0.4	10.8	$1.1x10^{4}$	$3.0x10^{5}$
Th-227	Thorium(90)	9	243	$1x10^{-2}$	0.270	$1.1x10^{3}$	$3.1x10^{4}$
Th-228		0.3	8.11	$4x10^{-4}$	$1.08x10^{-2}$	$3.0x10^{1}$	$8.2x10^{2}$
Th-229		0.3	8.11	$3x10^{-5}$	$8.11x10^{-4}$	$7.9x10^{-3}$	$2.1x10^{-1}$
Th-230		2	54.1	$2x10^{-4}$	$5.41x10^{-3}$	$7.6x10^{-4}$	$2.1x10^{-2}$
Th-231		40	1080	0.9	24.3	$2.0x10^{4}$	$5.3x10^{5}$
Th-232		Unlimited	Unlimited	Unlimited	Unlimited	$4.0x10^{-9}$	$1.1x10^{-7}$
Th-234		0.2	5.41	0.2	5.41	$8.6x10^{2}$	$2.3x10^{4}$
Th (natural)		Unlimited	Unlimited	Unlimited	Unlimited	$8.1x10^{-9}$	$2.2x10^{-7}$
Ti-44	Titanium(22)	0.5	13.5	0.2	5.41	6.4	$1.7x10^{2}$
Tl-200	Thallium(81.1)	0.8	21.6	0.8	21.6	$2.2x10^{4}$	$6.0x10^{5}$
Tl-201		10	270	10	270	$7.9x10^{3}$	$2.1x10^{5}$
Tl-202		2	54.1	2	54.1	$2.0x10^{3}$	$5.3x10^{4}$
Tl-204		4	108	0.5	13.5	$1.7x10^{1}$	$4.6x10^{2}$
Tm-167	Thulium(69)	7	189	7	189	$3.1x10^{3}$	$8.5x10^{4}$
Tm-168		0.8	21.6	0.8	21.6	$3.1x10^{2}$	$8.3x10^{3}$
Tm-170		4	108	0.5	13.5	$2.2x10^{2}$	$6.0x10^{3}$
Tm-171		40	1080	10	270	$4.0x10^{1}$	$1.1x10^{3}$

120.795: continued

Table A-1: A_1 and A_2 Values for Radionuclides (continued)

Symbol of Radionuclide	Element and Atomic No.	A_1 (TBq)	A_1 (Ci)	A_2 (TBq)	A_2 (Ci)	Specific Activity (TBq/g)	Specific Activity (Ci/g)
U-230	Uranium(92)	40	1080	$1x10^{-2}$	0.270	$1.0x10^{3}$	$2.7x10^{4}$
U-232		3	81.1	$3x10^{-4}$	$8.11x10^{-3}$	$8.3x10^{-1}$	$2.2x10^{1}$
U-233		10	270	$1x10^{-3}$	$2.70x10^{-2}$	$3.6x10^{-4}$	$9.7x10^{-3}$
U-234		10	270	$1x10^{-3}$	$2.70x10^{-2}$	$2.3x10^{-4}$	$6.2x10^{-3}$
U-235		Unlimited	Unlimited	Unlimited	Unlimited	$8.0x10^{-8}$	$2.2x10^{-6}$
U-236		10	270	$1x10^{-3}$	$2.70x10^{-2}$	$2.4x10^{-6}$	$6.5x10^{-5}$
U-238		Unlimited	Unlimited	Unlimited	Unlimited	$1.2x10^{-8}$	$3.4x10^{-7}$
U (natural)		Unlimited	Unlimited	Unlimited	Unlimited	$2.6x10^{-8}$	$7.1x10^{-7}$
U (enriched 5% or less)		Unlimited	Unlimited	Unlimited	Unlimited	--	(Table A-3)
U (enriched > 5%)		10	270	$1x10^{-3}$	$2.70x10^{-2}$	--	(Table A-3)
U (depleted)		Unlimited	Unlimited	Unlimited	Unlimited	--	(Table A-3)
V-48	Vanadium(23)	0.3	8.11	0.3	8.11	$6.3x10^{3}$	$1.7x10^{5}$
V-49		40	1080	40	1080	$3.0x10^{2}$	$8.1x10^{3}$
W-178	Tungsten(74)	1	27.0	1	27.0	$1.3x10^{3}$	$3.4x10^{4}$
W-181		30	811	30	811	$2.2x10^{2}$	$6.0x10^{3}$
W-185		40	1080	0.9	24.3	$3.5x10^{2}$	$9.4x10^{3}$
W-187		2	54.1	0.5	13.5	$2.6x10^{4}$	$7.0x10^{5}$
W-188		0.2	5.41	0.2	5.41	$3.7x10^{2}$	$1.0x10^{4}$
Xe-122	Xenon(54)	0.2	5.41	0.2	5.41	$4.8x10^{4}$	$1.3x10^{6}$
Xe-123		0.2	5.41	0.2	5.41	$4.4x10^{5}$	$1.2x10^{7}$
Xe-127		4	108	4	108	$1.0x10^{3}$	$2.8x10^{4}$
Xe-131m		40	1080	40	1080	$3.1x10^{3}$	$8.4x10^{4}$
Xe-133		20	541	20	541	$6.9x10^{3}$	$1.9x10^{5}$
Xe-135		4	108	4	108	$9.5x10^{4}$	$2.6x10^{6}$
Y-87	Yttrium(39)	2	54.1	2	54.1	$1.7x10^{4}$	$4.5x10^{5}$
Y-88		0.4	10.8	0.4	10.8	$5.2x10^{2}$	$1.4x10^{4}$
Y-90		0.2	5.41	0.2	5.41	$2.0x10^{4}$	$5.4x10^{5}$
Y-91m		2	54.1	2	54.1	$1.5x10^{6}$	$4.2x10^{7}$
Y-91		0.3	8.11	0.3	8.11	$9.1x10^{2}$	$2.5x10^{4}$
Y-92		0.2	5.41	0.2	5.41	$3.6x10^{5}$	$9.6x10^{6}$
Y-93		0.2	5.41	0.2	5.41	$1.2x10^{5}$	$3.3x10^{6}$
Yb-169	Ytterbium(70)	3	81.1	3	81.1	$8.9x10^{2}$	$2.4x10^{4}$
Yb-175		30	811	0.9	24.3	$6.6x10^{3}$	$1.8x10^{5}$
Zn-65	Zinc(30)	2	54.1	2	54.1	$3.0x10^{2}$	$8.2x10^{3}$
Zn-69m		2	54.1	0.5	13.5	$1.2x10^{5}$	$3.3x10^{6}$
Zn-69		4	108	0.5	13.5	$1.8x10^{6}$	$4.9x10^{7}$
Zr-88	Zirconium(40)	3	81.1	3	81.1	$6.6x10^{2}$	$1.8x10^{4}$
Zr-93		40	1080	0.2	5.41	$9.3x10^{-5}$	$2.5x10^{-3}$
Zr-95		1	27.0	0.9	24.3	$7.9x10^{2}$	$2.1x10^{4}$
Zr-97		0.3	8.11	0.3	8.11	$7.1x10^{4}$	$1.9x10^{6}$

120.795: continued

Table A-2: General Values for A_1 and A_2				
	A_1		A_2	
Contents	TBq	Ci	TBq	Ci
Only beta- or gamma-emitting nuclides are known to be present.	0.2	5	0.02	0.5
Alpha-emitting nuclides are known to be present, or no relevant data are available.	0.10	2.70	$2x10^{-5}$	$5.41x10^{-4}$

Table A-3: Activity-Mass Relationships for Uranium

Uranium Enrichment* weight % U-235 present	Specific Activity Ci/g	Tbq/g
0.45	$1.8x10^{-8}$	$5.0x10^{-7}$
0.72	$2.6x10^{-8}$	$7.1x10^{-7}$
1.0	$2.8x10^{-8}$	$7.6x10^{-7}$
1.5	$3.7x10^{-8}$	$1.0x10^{-6}$
5.0	$1.0x10^{-7}$	$2.7x10^{-6}$
10.0	$1.8x10^{-7}$	$4.8x10^{-6}$
20.0	$3.7x10^{-7}$	$1.0x10^{-5}$
35.0	$7.4x10^{-7}$	$2.0x10^{-5}$
50.0	$9.3x10^{-7}$	$2.5x10^{-5}$
90.0	$2.2x10^{-6}$	$5.8x10^{-5}$
93.0	$2.6x10^{-6}$	$7.0x10^{-5}$
95.0	$3.4x10^{-6}$	$9.1x10^{-5}$

*The figures for uranium include representative values for the activity of the uranium-235 which is concentrated during the enrichment process.